Inter-Comparison of Model Performance of Meteorological Simulations Using MM5 Versions 3.6.3 and 3.7.4

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Table of Contents

List of Figures

List of Tables

1. Introduction

Annual continental-scale air quality simulations require implementation of a modeling system consisting of three components: a meteorological model, emissions model, and photochemical transport model. The meteorological component generates a large database of surface and three dimensional meteorological fields, which serve as input to the emissions and photochemical models. Annual meteorological simulations have been previously conducted for the years of 1996, 2001, 2002, and 2005 (Olerud et al., 2000; McNally, 2003; Johnson, 2004; Baker et al., 2007). A 2002 annual simulation was conducted by the Iowa Department of Natural Resources (IDNR). New annual simulations will be required to support future state and federal planning activities. Such simulations will be designed to provide the base year meteorological data from which air quality modeling efforts can proceed. The purpose of this document is to provide an overview of meteorological modeling processes, with a focus upon a sensitivity study evaluating model performance as a function of model version and Portland Group, Inc., compiler version.

Since uncertainties in meteorological model results will be carried over into emissions and photochemical model simulations, an understanding of the performance of the meteorological model used is imperative. Many analysis methods are available to both quantitatively and qualitatively assess the accuracy and representativeness of modeled meteorological variables, such as temperature, wind speed and direction, and relative humidity. Emery et al. (2001) provide a set of statistical benchmarks to measure meteorological model performance of daily surface variables. Other analysis methods include qualitative comparison of modeled and observed soundings and modeled and observed precipitation.

Since the completion of the IDNR 2002 annual simulation, which used the Pennsylvania State University/National Center For Atmospheric Research Fifth Generation Mesoscale Model (MM5) version 3.6.3, a new major release of MM5 (version 3.7) was released by the University Corporation for Atmospheric Research[1]. This release contains various bug fixes and improvements for all pre-processors and model code. Therefore, when running the next annual simulation the choice must be made whether or not to use the newest release of MM5. The purpose of this study is to determine any improvement in model performance with version 3.7 (latest minor release is 3.7.4). This analysis compares the results of four simulations run using MM5 versions 3.6.3 and 3.7.4. Each simulation consists of a 5-day block in 2002. Two simulations occur adjacently in the summer, while the other two are adjacent during the winter. The performances of the simulations run with the two versions of MM5 are compared using three analysis methods. First, statistical measures of performance of modeled surface fields are calculated for each version of MM5 and compared. Second, modeled upper-air soundings are compared against observed soundings to give a qualitative comparison of the output of the two MM5 versions. Lastly, model-predicted precipitation accumulated during the simulation time blocks is compared to observed precipitation accumulated over the same time period. These three analyses give a basic comparison of the performance of the two MM5 versions, and the conclusions reached will determine the most appropriate version of MM5 to use in future annual simulations.

[1] For more information on MM5, refer to http://www.mmm.ucar.edu/mm5.

In addition to comparing the two versions of MM5, the models are compiled with several versions of the Portland Group compiler to determine if the compiler version used influences model results and/or if any particular compiler version significantly affects model performance, as has been observed in air quality simulations under certain conditions.[2]

[2] On certain CPUs (Intel 32-bit chips with SSE2 optimization) significant differences in nitrate concentrations predicted by the CAMx air quality model have been observed when compiling the model code with PGI v6.1 versus v6.0.

2. Methodology

2.1. MM5 Modeling System Configuration

Version 3.6.3 of the MM5 modeling system was utilized for the 2002 IDNR annual simulation (Johnson 2004). Detailed information on the model configuration, including domain structures, vertical layer structure, observational data assimilation method, physics parameterization configurations, and other pre-processor settings used in that study can be found in Johnson (2004). All model configurations were preserved for this study and are identical for both versions 3.6.3 and 3.7.4. The horizontal domain was based on a Lambert Conic Conformal map projection centered at 40° N latitude, 90° W longitude, with true latitudes of 33 and 45° N. Table 2-1 and Figure 2-1 show the horizontal domain configurations, while

Table 2-2 describes the vertical sigma-coordinate structure used in the model configuration. Table 2-3 lists the physics parameterizations used.

Table 2-1. Grid Characteristics of Course and Nested Domain, With Specifications Referring To Dot Points.

Grid	Resolution (km)	NX	NY	Nest Location (x,y)	Southwest Coordinate (km offset)
1	36	165	129	1,1	(-2952, -2304)
2	12	193	199	66,30	(-612, -1260)

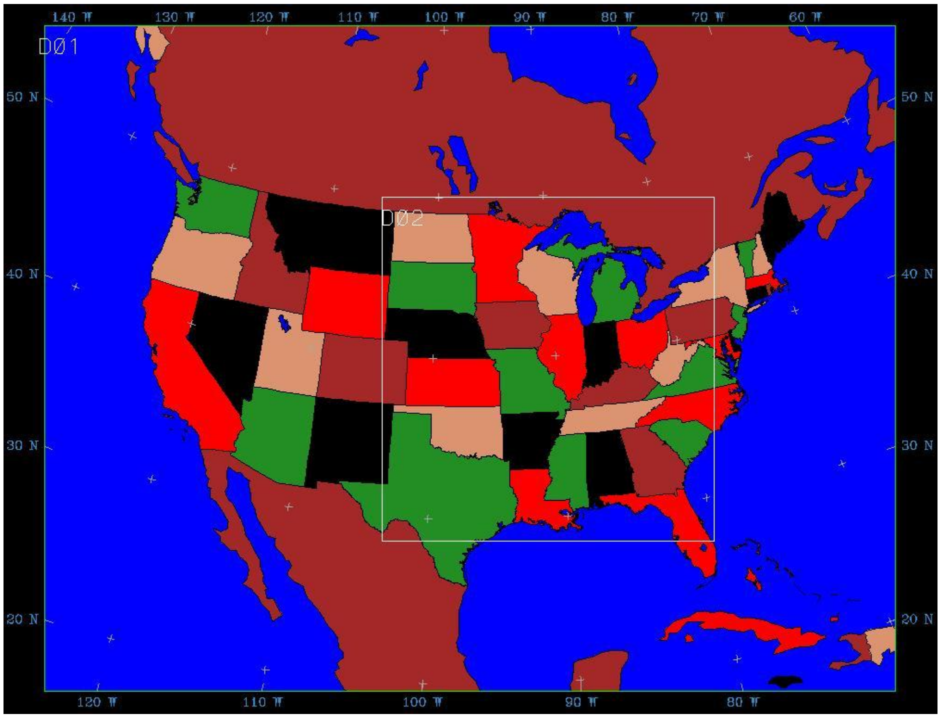

Figure 2-1. The 36 km course (D01) and 12 km nested (D02) IDNR modeling domains.

Table 2-2. Vertical Sigma-Coordinate Level Structure.

Level	Sigma	Height (m)	p (mb)	Depth (m)	Level	Sigma	Height (m)	p (mb)	Depth (m)
34	0.000	14662	100	1841	16	0.820	1400	838	166
33	0.050	12822	145	1466	15	0.840	1235	856	163
32	0.100	11356	190	1228	14	0.860	1071	874	160
31	0.150	10127	235	1062	13	0.880	911	892	158
30	0.200	9066	280	939	12	0.900	753	910	78
29	0.250	8127	325	843	11	0.910	675	919	77
28	0.300	7284	370	767	10	0.920	598	928	77
27	0.350	6517	415	704	9	0.930	521	937	76
26	0.400	5812	460	652	8	0.940	445	946	76
25	0.450	5160	505	607	7	0.950	369	955	75
24	0.500	4553	550	569	6	0.960	294	964	74
23	0.550	3984	595	536	5	0.970	220	973	74
22	0.600	3448	640	506	4	0.980	146	982	37
21	0.650	2942	685	480	3	0.985	109	987	37
20	0.700	2462	730	367	2	0.990	73	991	36
19	0.740	2095	766	266	1	0.995	36	996	36
18	0.770	1828	793	259	0	1.000	0	1000	0
17	0.800	1569	820	169					

Table 2-3. Physics Parameterization Configuration Used in 2002 IDNR MM5 Annual Simulation.

Option	Configuration	Details
Microphysics	Mixed-Phase (Reisner I)	
Cumulus Scheme	Kain-Fritsch 2	
Planetary Boundary Layer (PBL)	Asymmetric Convective Model[3]	Required by Pleim-Xiu LSM
Radiation	RRTM	Calculated every 15 minutes
Land Surface Model	Pleim-Xiu	No continuous soil fields
Shallow Convection	Not enabled	
SST Data source	Eta Skin-Temperature	
Snow Cover Effects	Considered	IFSNOW=1
Timestep	90 seconds	(PX uses an internal 40s timestep)

2.2. Simulation and Computational Setup

The two versions of MM5 are integrated in five day blocks similar to the 2002 IDNR annual simulation. Two adjacent blocks are chosen from the 2002 setup to re-create summer conditions, while two adjacent blocks are chosen to re-create winter conditions. Table 2-4 shows the start and end dates for each block. Note the overlap in time for each adjacent block allows for avoiding the use of data during spin-up time at the beginning of each simulation while maintaining continuity in the data.

[3] The Asymmetric Convective Model (ACM) is also referred to as the Pleim-Chang PBL. The ACM parameterization is a derivative of the Blackadar scheme (Pleim and Chang, 1992).

The eight possible combinations of MM5 version and simulation block were run on four Linux workstations. Each workstation ran two adjacent blocks simultaneously and thus was responsible for simulating a single season. Table 2-5 describes the scenarios run on each workstation. Each Linux workstation was equipped with dual 3.06 GHz Intel Pentium Xeon

Table 2-4. Starting and Ending Dates for Each 5-Day Simulation Block.

Block	Starting Date (yy-mm-dd:hh)	Ending Date (yy-mm-dd:hh)
2002-07-04	2002-07-04:12Z	2002-07-09:12Z
2002-07-08	2002-07-08:12Z	2002-07-13:12Z
2002-12-03	2002-12-03:12Z	2002-12-08:12Z
2002-12-07	2002-12-07:12Z	2002-12-12:12Z

Table 2-5. Computational Setup of MM5 Simulations.

Workstation	Scenario
Node1	v3.6.3-summer
Node2	v3.6.3-winter
Node3	v3.7.4-summer
Node4	v3.7.4-winter

processors, 2.0 Gb of RAM, and Ultra 320 SCSI local hard drives for model I/O. Although each processor on any give workstation was tasked with one simulation, Open MP was not an available option, due to the implementation of the Pleim-Xiu land-surface model. Approximately 96 wall-clock hours were required for each workstation to run two simulations simultaneously. Storage requirements for model output from all simulations reached approximately 93 Gb, with the 36 km simulations occupying 33 Gb and the 12 km simulations occupying 60 Gb of storage space.

Three versions of the Portland Group compiler, 5.1, 6.0, and 6.1, are used to compile the MM5 pre-processor and model code to determine any influence the compiler has on model results. To test this, the computational setup in Table 2-5 is implemented for the first compiler version, MM5 is run on all workstations, and the model output files are moved to a new directory for storage. For organizational and practical purposes, both versions of MM5 are stored on a separate computer and only the executable and other necessary files are copied over to run on the workstations in Table 2-5. Both versions of MM5 pre-processors and model code are re-compiled on the original machine using the next compiler version, and the executable and other necessary files are again copied over and run on the workstations in Table 2-5. This process is repeated until both versions of MM5 have been run with code compiled using all compiler versions, producing model output for all four time blocks in Table 2-4, both MM5 versions, and all three compiler versions, or 24 blocks total.

2.3. <u>Performance Analysis</u>

The strategy for evaluating and comparing model performance in this study follows the same operational criteria as in the 2002 MM5 annual simulation conducted by IDNR. Statistical measures are used to evaluate the performance of modeled variables temperature, wind speed and direction, and relative humidity at the surface. To achieve the optimal sampling size the IDNR MM5 domain is broken down into the same sub-regions used in the 2002 annual simulations (Figure 2-2). The basis of the statistical evaluation is formed from the comparison of modeled surface data to Techniques Data Laboratory U.S. and Canada surface hourly observations (ds472.0). The performance statistics are calculated on a set of observation-model predicted data pairs at observation locations, where modeled values are interpolated from the

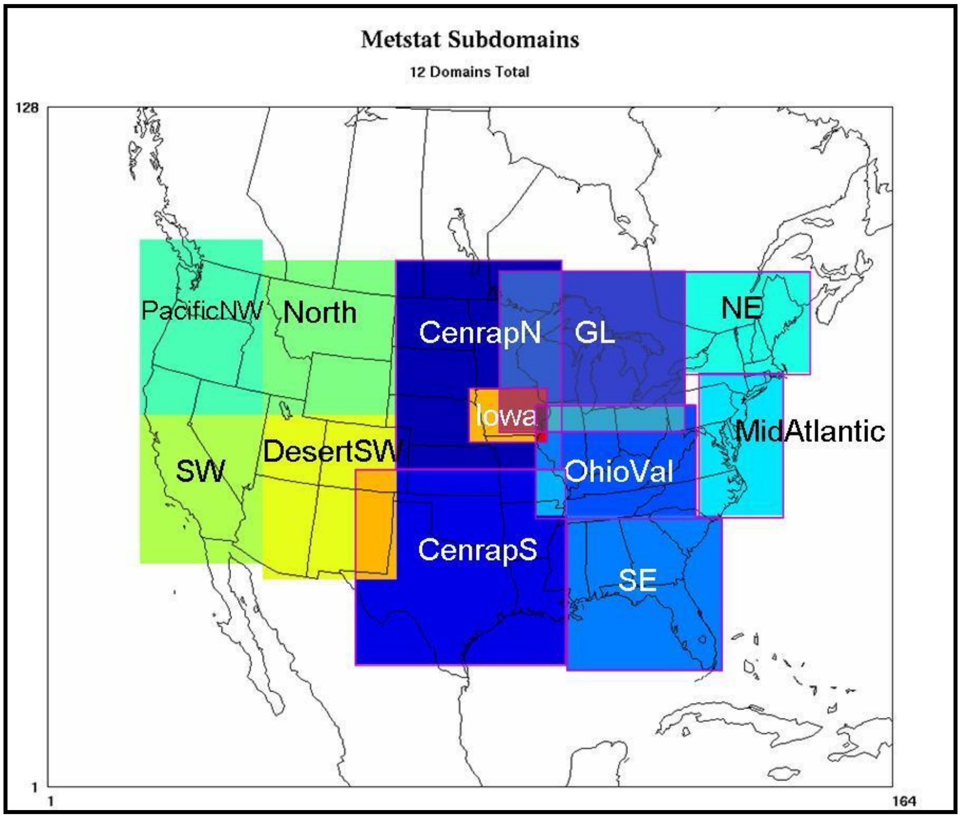

Figure 2-2. Decomposition of the IDNR MM5 domain into rectangular sub-regions for use in statistical evaluation of model performance. Areas of overlap are shaded differently and outlines have been added to highlight individual sub-domain boundaries.

model grid. The statistics associated with a particular sub-region in Figure 2-2 are calculated using all observation-prediction pairs located within that rectangular area. Hourly and daily averaged bias and root mean square error (RMSE) for temperature, wind speed and direction, and humidity were generated using the Metstat program and an associated Microsoft Excel post-processing macro developed by Environ. Time series of modeled and observed conditions were also prepared via Metstat.

Bias error is defined as the mean difference between observed and predicted values of a parameter. A bias closer to zero indicates better model performance, with a negative value indicating under-prediction and positive value indicating an over-prediction. Root mean square error describes the differences in observed-predicted pairs in an absolute sense, or regardless of whether the predicted value is less than or greater than the observed value. The sign is eliminated by squaring the difference in each observed-predicted pair. RMSE is defined mathematically as the square root of the mean squared difference between observed and predicted pairs. One drawback of RMSE, however, is it can be inflated by a single extreme modeled value, since each difference is squared. Thus, the RMSE associated with a set of paired values covering a particular region can be misleading due to a single or small set of observed-predicted pairs.

In any model performance evaluation an analysis of upper-air model output data should be included. Upper air features play a vital role in determining air quality conditions at the surface, and in atmospheric processes in general. However, the analysis of upper air model performance adds a degree of complexity far surpassing the difficulty in analyzing surface features. The density of the upper-air observation network comes nowhere near matching the density of gridded model output. The most practical method for assessing the performance of modeled upper air data is a qualitative comparison of observed soundings of temperature, dewpoint, and winds with model soundings generated at the nearest gridpoint. To generate this analysis, a software tool developed in-house, RAOBPLOT, is used to create plots of observed versus modeled soundings.

The final component in the comparison of model performance between the two versions of MM5 is a qualitative comparison of modeled versus observed precipitation. Precipitation is one of the largest uncertainties in numerical modeling, due to the scales and complexities of all processes involved. Although accumulated precipitation is technically a two-dimensional surface field, a precipitation analysis indirectly enhances the upper air review due to the three dimensional nature of precipitation processes.

In MM5, modeled precipitation is output in terms of rainfall accumulated since the start of the simulation. Daily rainfalls totals must be calculated by subtracting the accumulated precipitation at the start of the day from that at the end of the day for each grid cell. Successive daily values are then summed across each adjacent pair of simulation blocks to provide an 8-day accumulated precipitation estimate (each block yields four valid daily rainfall totals).

The observed precipitation data is a gridded analysis of rain-gauge data from the Climate Prediction Center[4]. This data set contains daily precipitation measurements obtained from rain gauge networks operated by the River Forecast Center and Climate Anomaly Database. The precipitation data is quality controlled and analyzed to a latitude-longitude grid at 0.25 degree resolution using a modified Cressman scheme (Glahn et al. 1985; Charba et al. 1992). In order to validate the modeled precipitation, this data set must be regridded to the IDNR MM5 grid and daily totals added over the same time block as each simulation. The modeled and observed precipitation fields are visually compared to determine the performance of both versions of MM5.

[4] This data is available from the CPC Retrospective Analysis Website, http://www.cpc.ncep.noaa.gov/products/precip/realtime/retro.shtml.

3. Results

3.1. Surface Statistical Comparison

The results shown below are a comparison of the surface statistical performance of the two versions of MM5. Modeled (36 km domain) versus observed conditions were plotted, along with their associated error statistics in the form of bias and RMSE. The results focus on just the sub-regions CenrapN and Iowa, shown in Figure 2-2, which encompass the state of Iowa, as any more detail in the analysis will only reiterate the results of the 2002 annual simulation.

Figure 3-1 through Figure 3-3 show the summer statistics for wind speed and direction, temperature, and humidity for the CenrapN sub-region, while Figure 3-4 through Figure 3-6 show the same results for the Iowa sub-region. For the summer period, the performances of the two model versions were generally quite similar. The statistics for wind speed and direction, shown in Figure 3-1 and Figure 3-4, were nearly identical. The RMSE and bias for wind speed and direction generally fell within the statistical benchmarks described by Emery et al. (2001). However, RMSE peaked during diurnal peaks in wind speed due to the under-prediction of the diurnal wind speed maxima in summer. The same assessment held true for modeled temperature. However, peaks in RMSE occurred due to over-prediction of diurnal maxima in the CenrapN domain and diurnal minima in the Iowa domain. Trends in mixing ratio over the summer period were nearly identical, though modeled mixing ratio values were slightly lower across the entire time period for the newer version. Like version 3.6.3, version 3.7.4 struggled to correctly capture the diurnal variability in humidity, and thus produced similar peaks in RMSE.

Figure 3-7 through Figure 3-9 display the winter statistics for wind speed and direction, temperature, and humidity for the CenrapN sub-region, while Figure 3-10 through Figure 3-12 display those statistics for the Iowa sub-region. Again, the performances of modeled wind speed and direction were nearly identical, however, weaker than the summer results. Neither model version successfully recreated the diurnal variability in windspeed, as was done in the summer period. The performance in modeled temperature was very similar between the two versions in the first half of the winter block. Diurnal temperature variations during this time were minimal and the level temperature profile was easily re-created by both versions of MM5. During the last half of the time period, however, diurnal temperature variations increased and were superimposed on a linearly increasing trend. This general trend was modeled more successfully in version 3.6.3 than in version 3.7.4, resulting in a greater negative bias and larger RSME in modeled temperature for version 3.7.4. A comparison of modeled mixing ratio performance for the winter period yielded results similar to the comparison of temperature. However, in winter mixing ratio values are very low and thus large errors will not typically be observed.

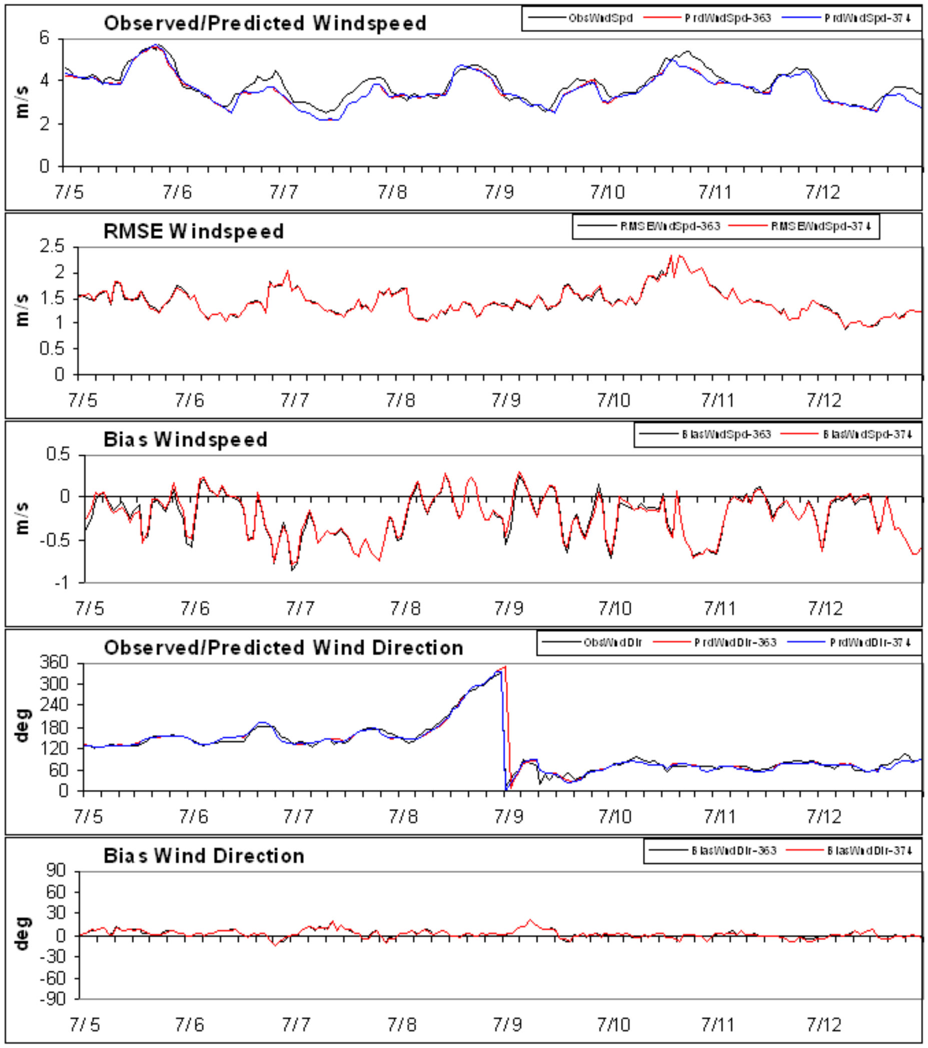

Figure 3-1. Model performance statistics of wind speed and direction for the summer blocks in the CenrapN sub-region for MM5 versions 3.6.3 and 3.7.4.

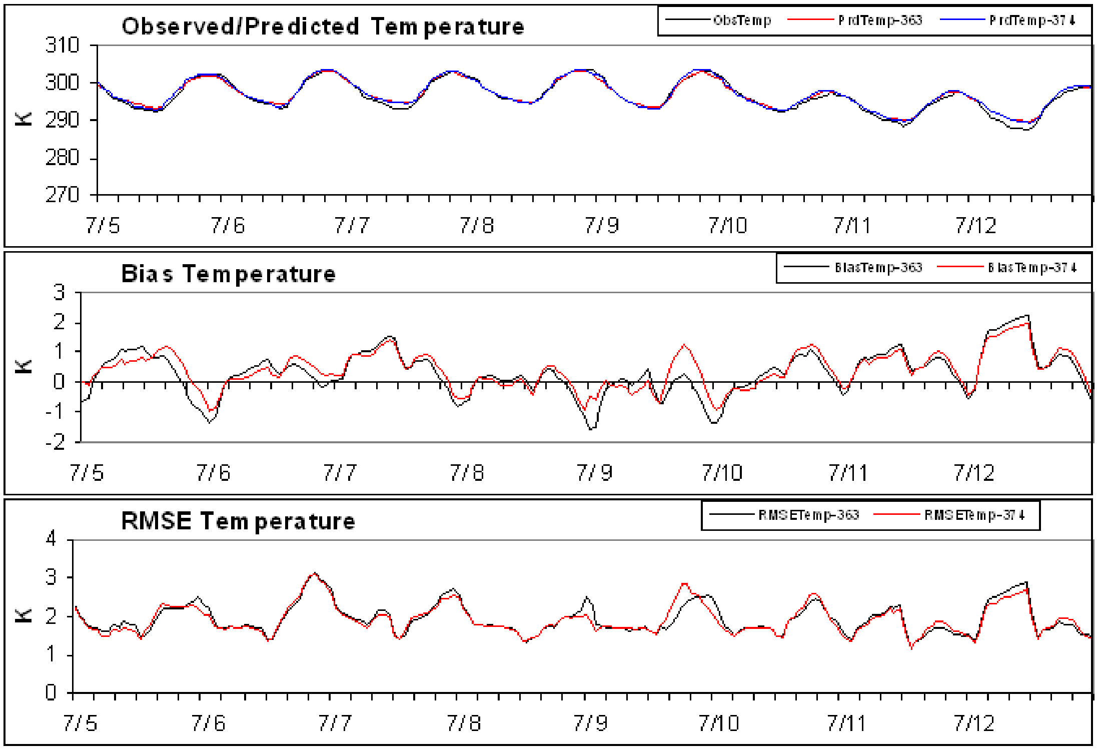

Figure 3-2. Model performance statistics of temperature for the summer blocks in the CenrapN sub-region for MM5 versions 3.6.3 and 3.7.4.

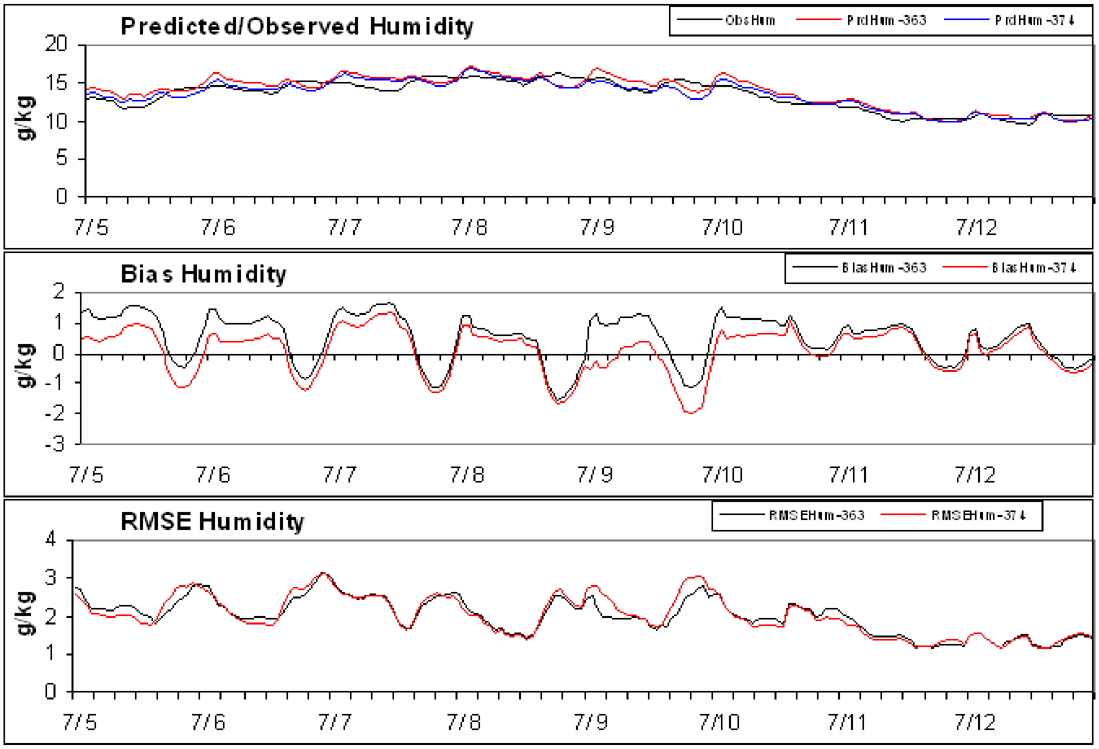

Figure 3-3. Model performance statistics of mixing ratio for the summer blocks in the CenrapN sub-region for MM5 versions 3.6.3 and 3.7.4.

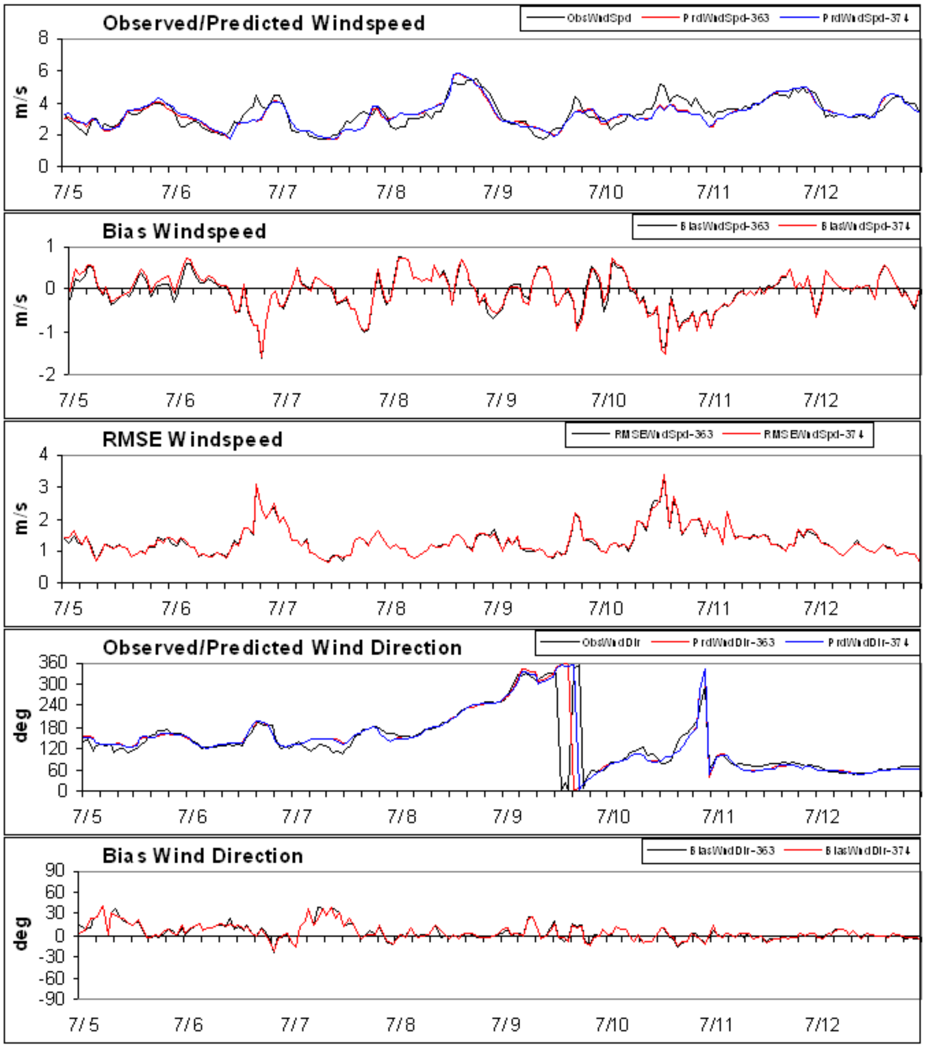

Figure 3-4. Model performance statistics of wind speed and direction for the summer blocks in the Iowa sub-region for MM5 versions 3.6.3 and 3.7.4.

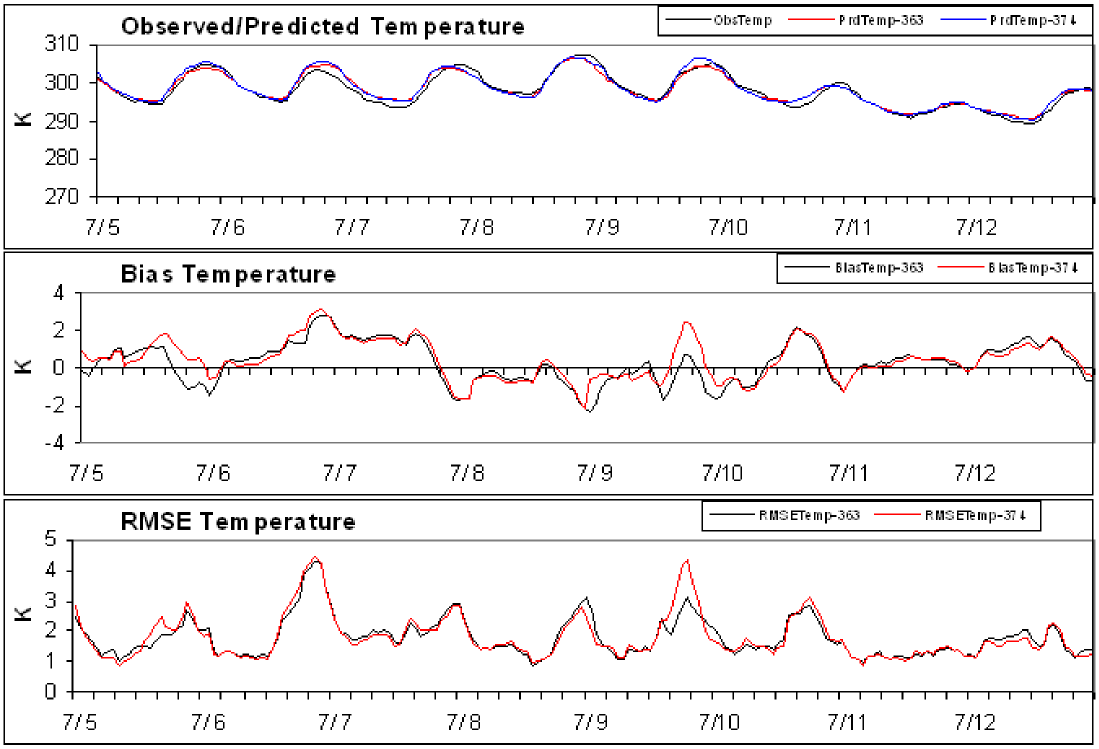

Figure 3-5. Model performance statistics of temperature for the summer blocks in the Iowa sub-region for MM5 versions 3.6.3 and 3.7.4.

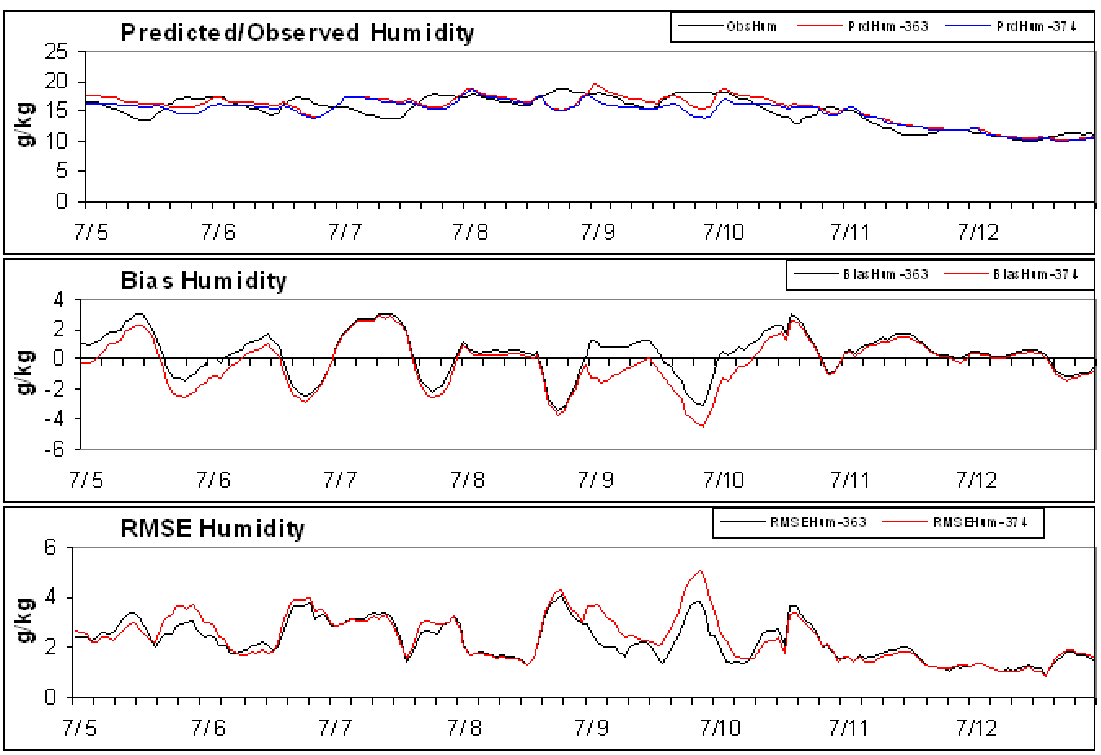

Figure 3-6. Model performance statistics of mixing ratio for the summer blocks in the Iowa sub-region for MM5 versions 3.6.3 and 3.7.4.

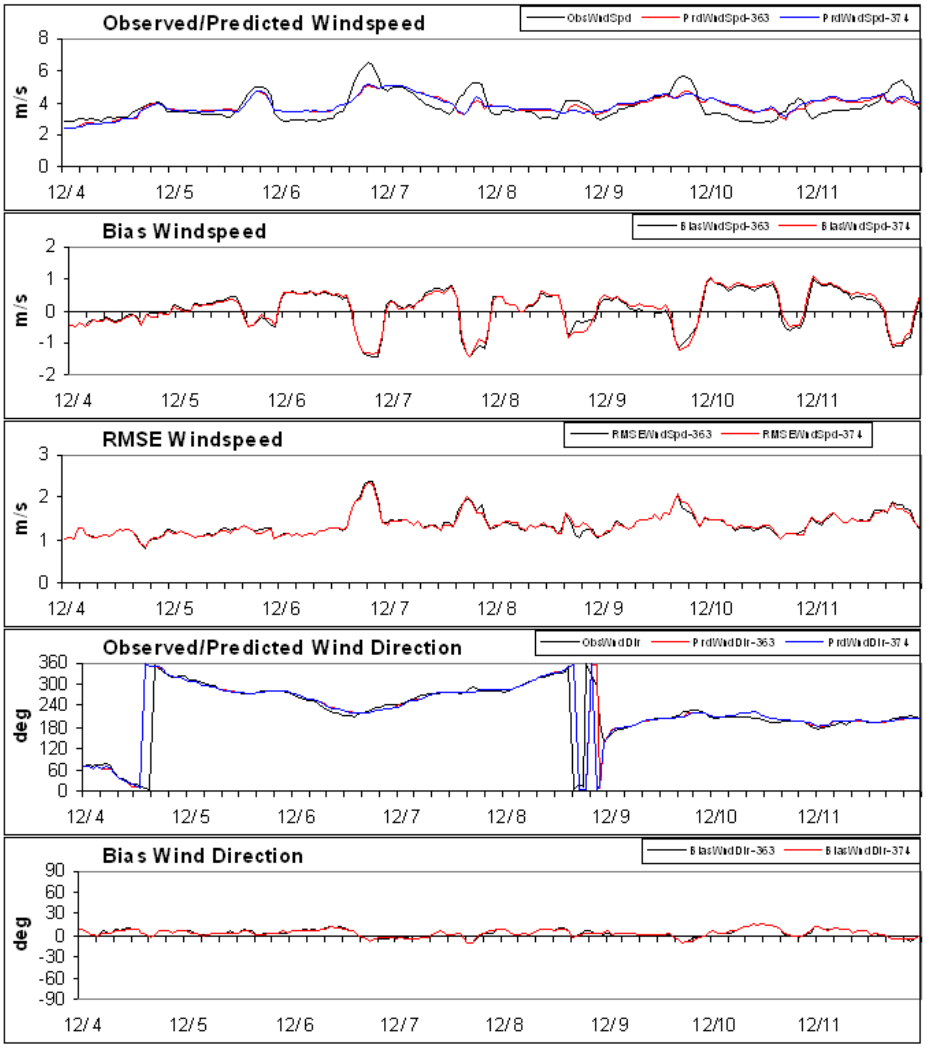

Figure 3-7. Model performance statistics of wind speed and direction for the winter blocks in the CenrapN sub-region for MM5 versions 3.6.3 and 3.7.4.

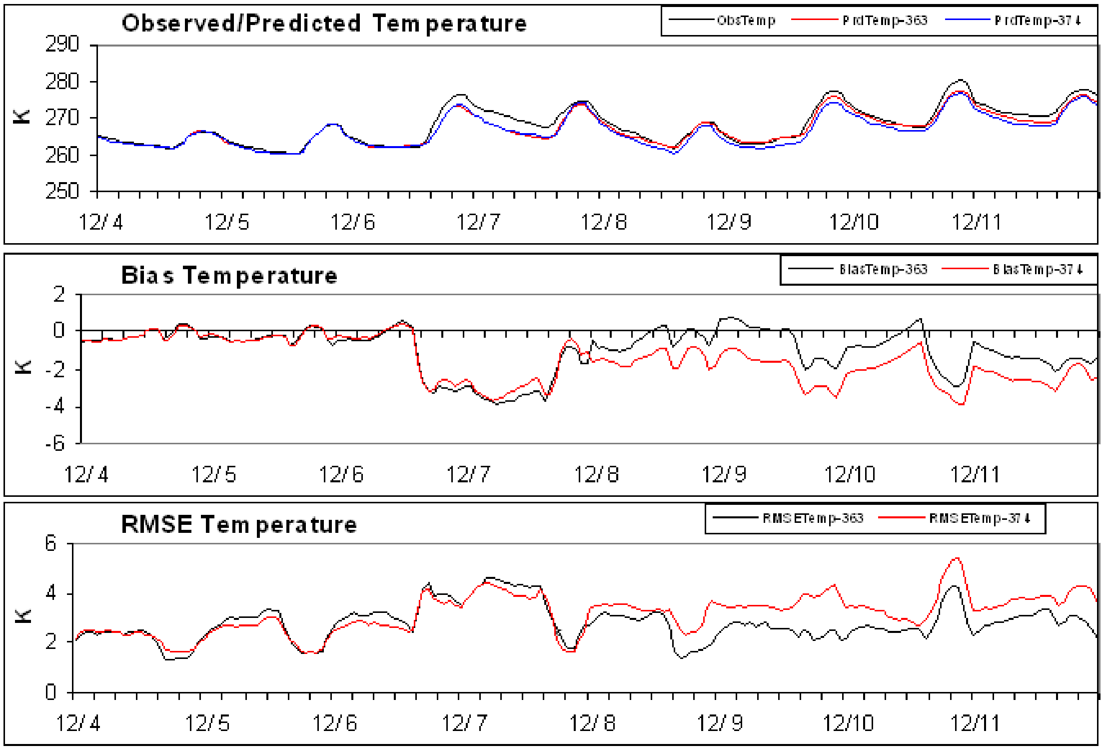

Figure 3-8. Model performance statistics of temperature for the winter blocks in the CenrapN sub-region for MM5 versions 3.6.3 and 3.7.4.

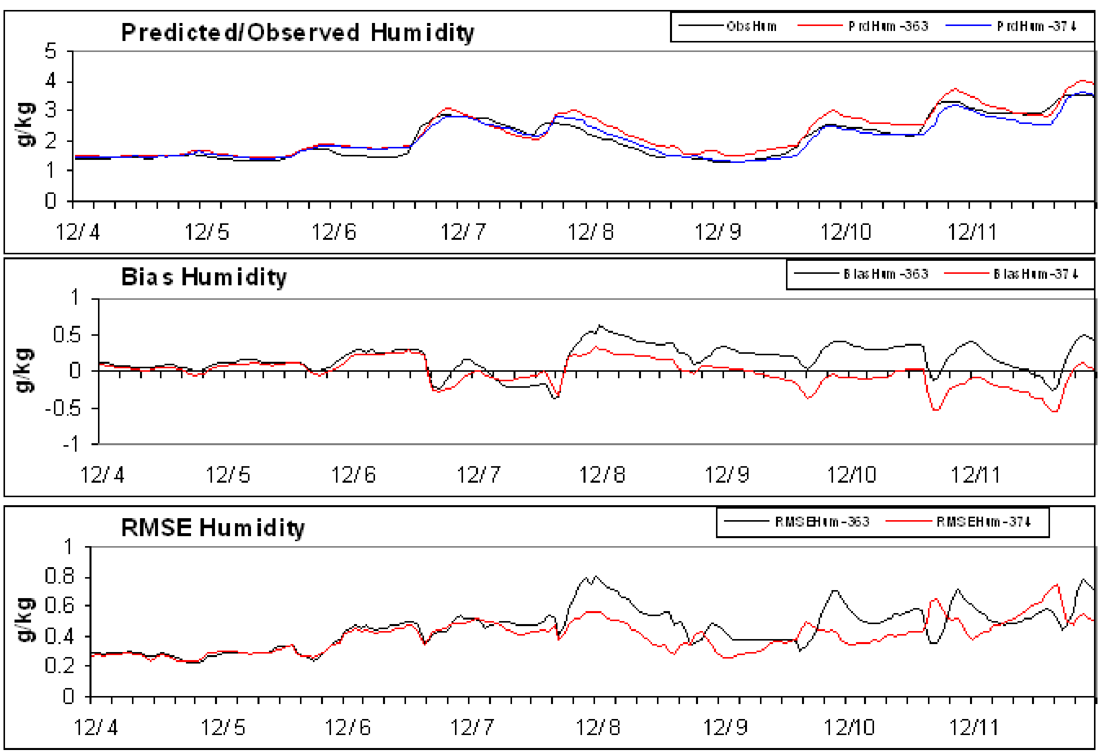

Figure 3-9. Model performance statistics of mixing ratio for the winter blocks in the CenrapN sub-region for MM5 versions 3.6.3 and 3.7.4.

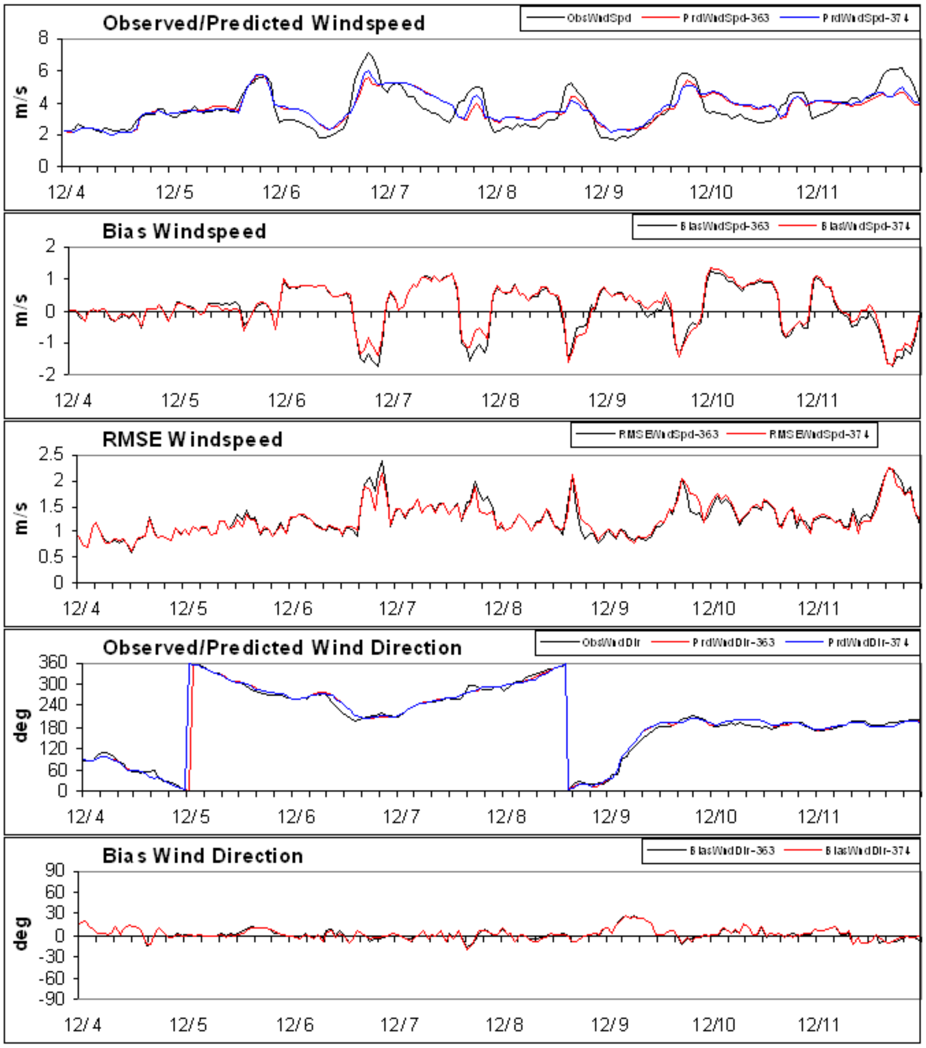

Figure 3-10. Model performance statistics of wind speed and direction for the winter blocks in the Iowa sub-region for MM5 versions 3.6.3 and 3.7.4.

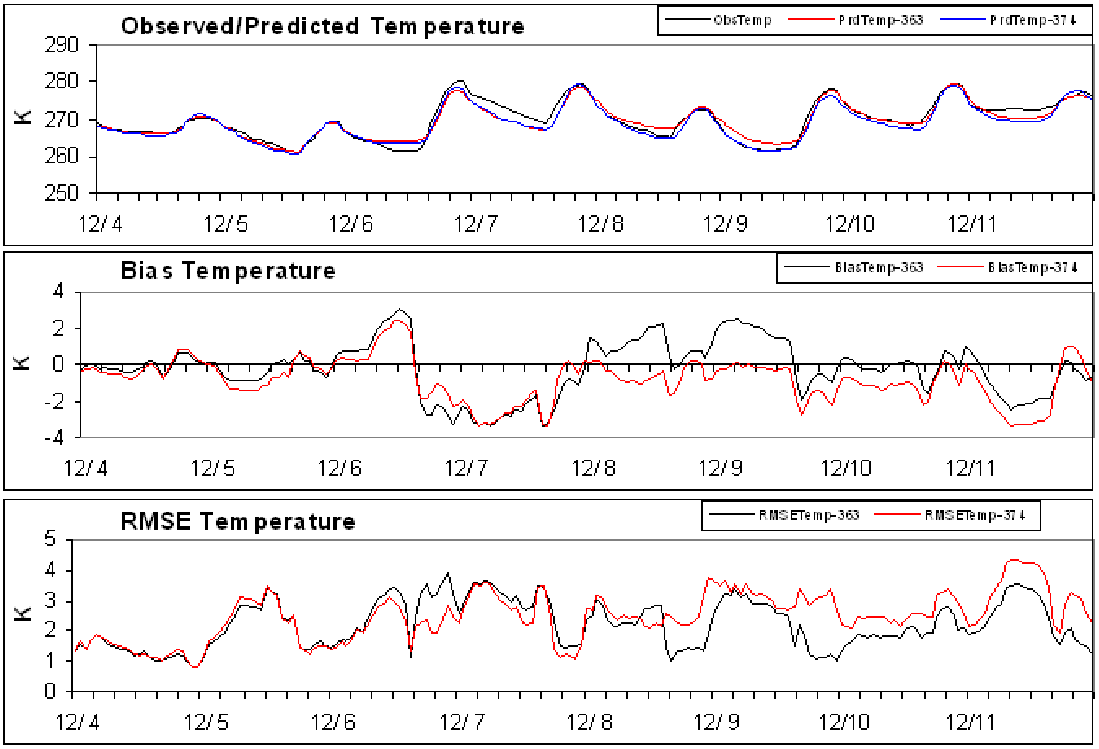

Figure 3-11. Model performance statistics of wind temperature for the winter blocks in the Iowa sub-region for MM5 versions 3.6.3 and 3.7.4.

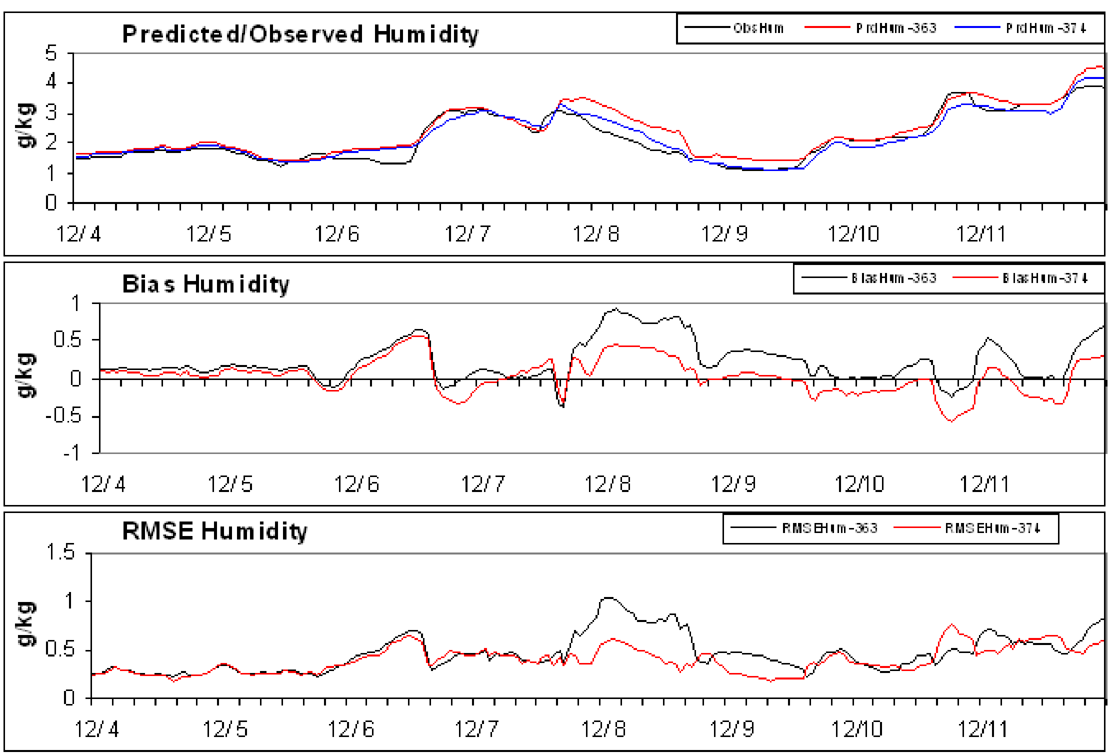

Figure 3-12. Model performance statistics of mixing ratio for the winter blocks in the Iowa sub-region for MM5 versions 3.6.3 and 3.7.4.

3.2. Upper-air Comparison

An analysis of upper air meteorology, such as vertical profiles of temperature, dewpoint, and wind velocity vectors, adds to the robustness of a model performance evaluation. The performance evaluation of the 2002 annual MM5 simulation yielded the following results in regards to the upper air evaluation of the observed versus modeled soundings over the Davenport, Iowa station during the simulated summer months: Upper level wind vectors are well simulated. The temperature fields below approximately 900 mb yielded a tendency toward under-prediction at 0Z, while the moisture fields were generally overstated during the same region and time. At 12Z, temperatures were generally under-predicted below 900 mb. In terms of estimated PBL depths, the mixed layer commonly appears shallower than observed. While error is never desired, in terms of modeling air quality (in a conservative sense) a shallow PBL is preferred versus excessive depth (Johnson, 2004).

Using the same analysis tool, RAOBPLOT, modeled soundings produced by MM5 versions 3.6.3 and 3.7.4 were compared against observed soundings, as well as each other, to determine which version better simulates meteorological fields in the upper atmosphere. The observed versus modeled soundings are shown from Figure 3-13 to Figure 3-20, with the first four representing summer conditions and the other four representing winter conditions. Since RAOBPLOT was not designed to plot soundings from multiple model runs, the soundings produced by both MM5 versions for any given time are compared by placing them side-by-side in each figure.

For daytime soundings (0Z) results from both versions are nearly identical for the upper atmosphere above about 700 mb. Both versions adequately modeled temperature throughout the entire depth, while adequately modeling dewpoint up to 400 mb then over-predicting dewpoint up to the top of the model. Version 3.7.4 results show the boundary layer mixing slightly higher during the day than the previous version, a result which improves the accuracy of the PBL depth prediction. Version 3.7.4 modeled lower dewpoints in the boundary layer than version 3.6.3 when the boundary layer was well mixed. This would likely result in lower modeled concentrations of secondarily-formed particulates, such as ammonium nitrate and ammonium sulfate, whose gas-to-particle conversion process in the atmosphere is dependent on relative humidity. Summer, nighttime soundings (12Z) were nearly identical for both versions of MM5. All winter soundings for both versions were also nearly identical.

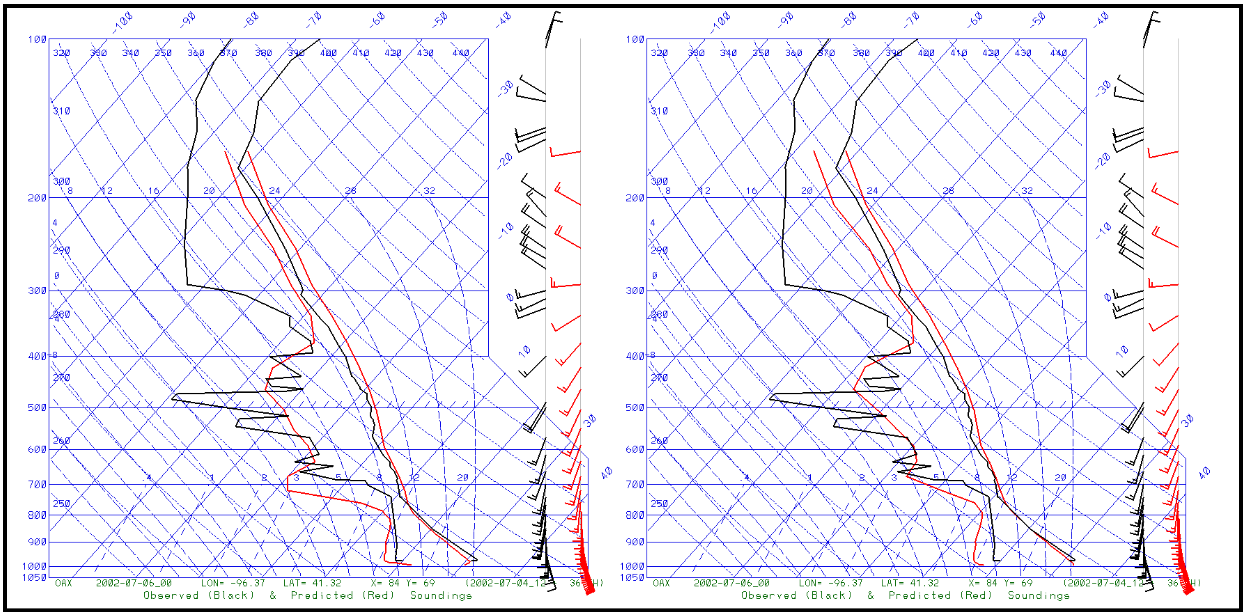

Figure 3-13. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 00Z 6 July 2002.

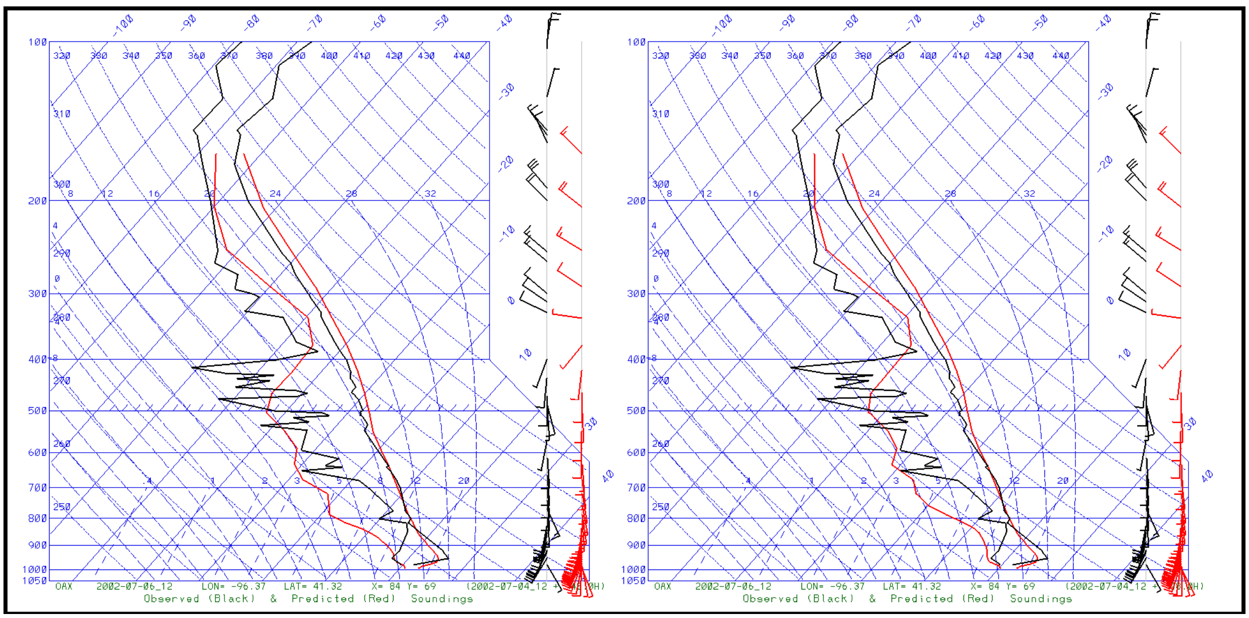

Figure 3-14. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 12Z 6 July 2002.

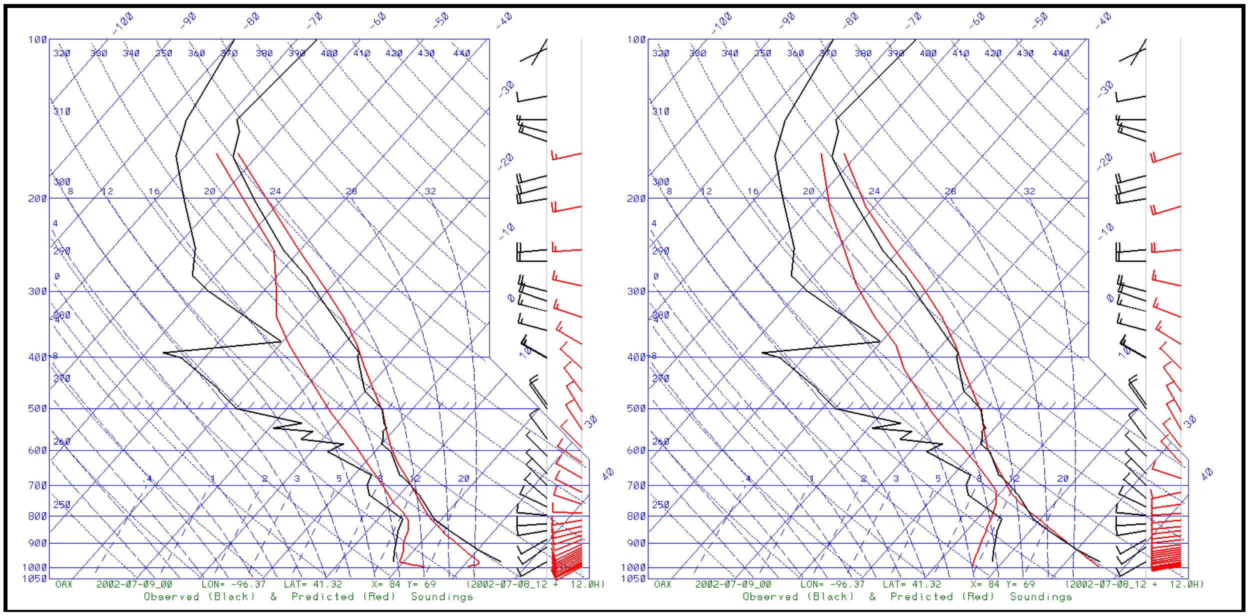

Figure 3-15. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 00Z 9 July 2002.

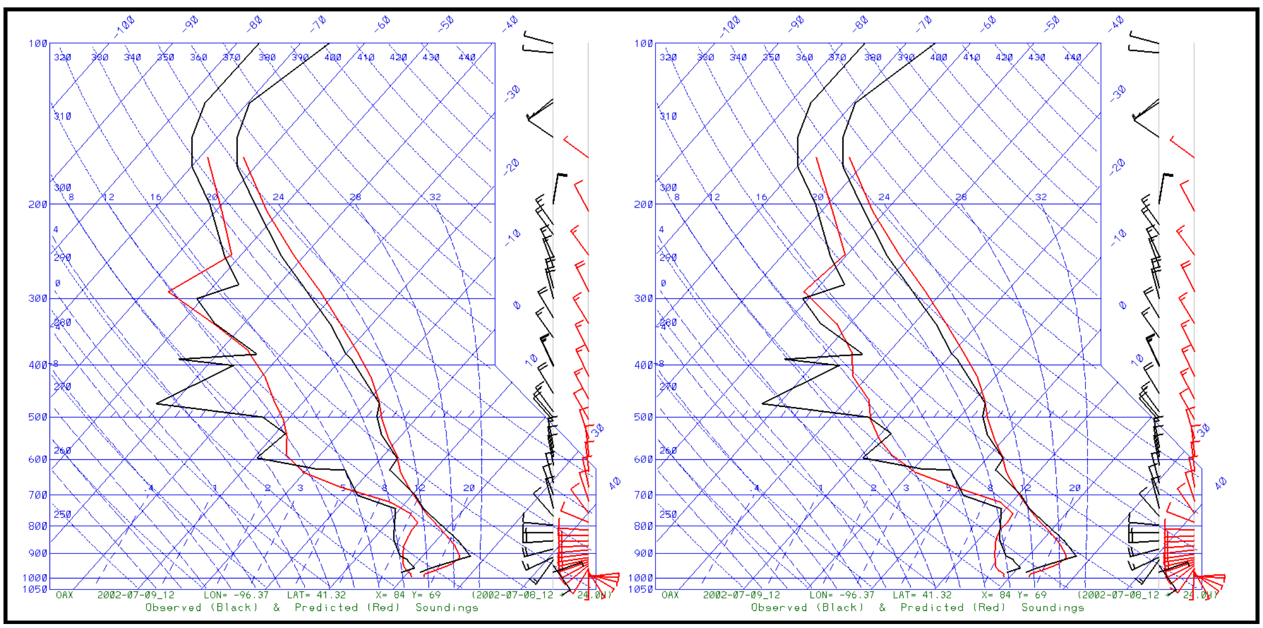

Figure 3-16. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 12Z 9 July 2002.

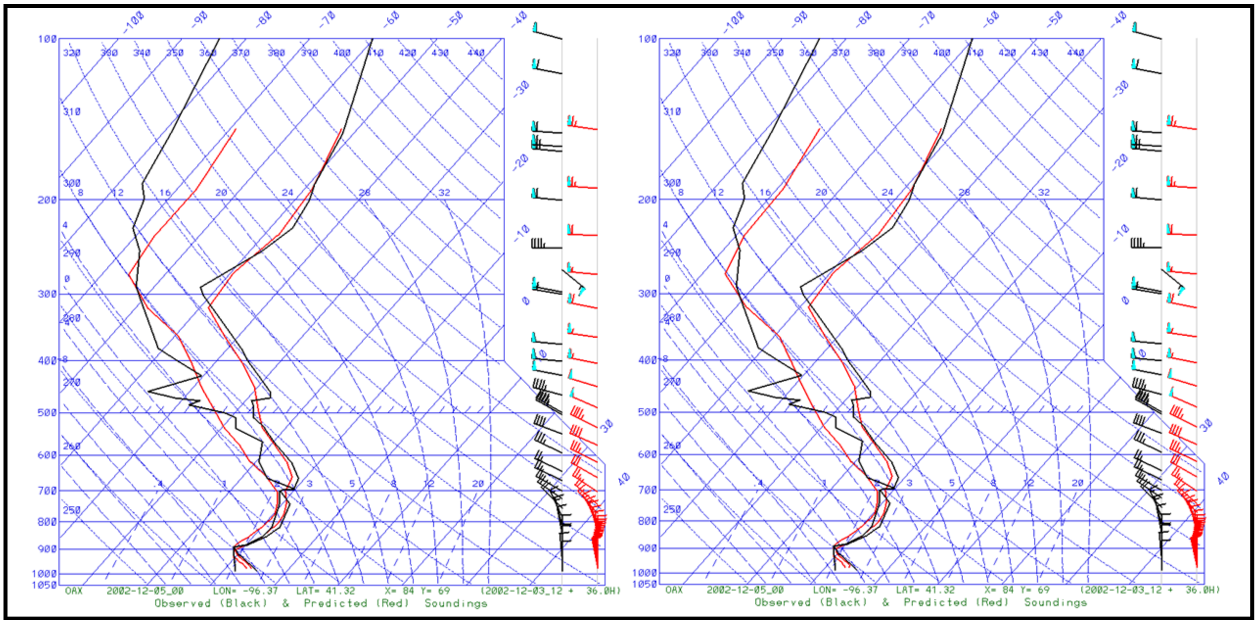

Figure 3-17. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 00Z 5 December 2002.

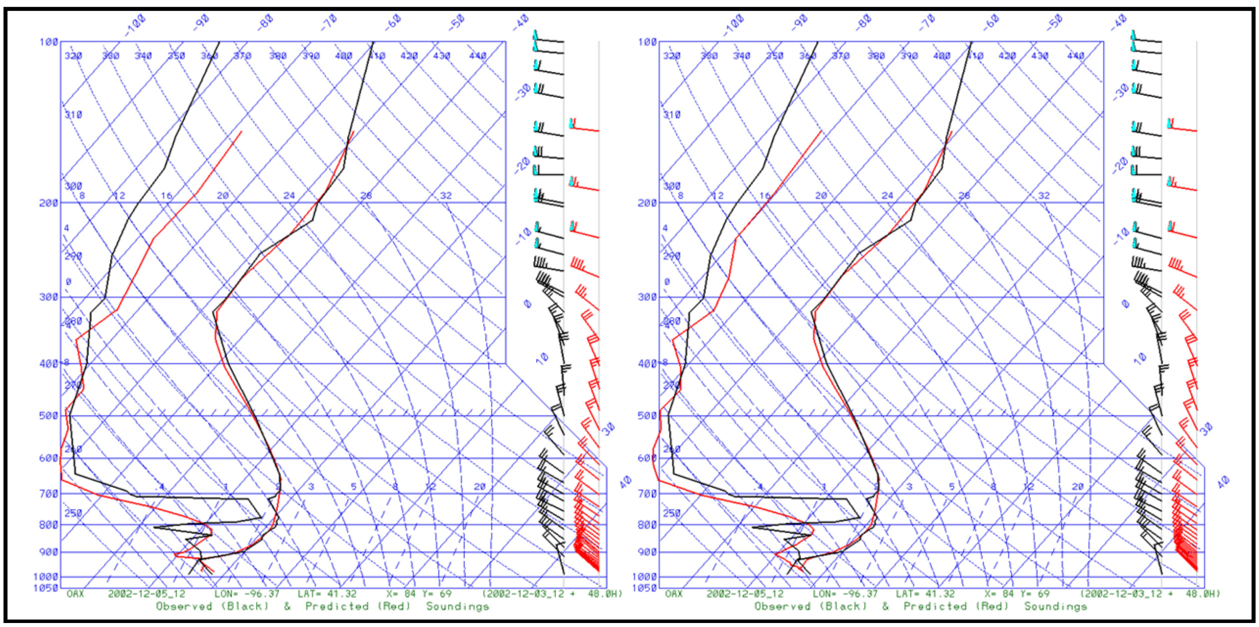

Figure 3-18. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 12Z 5 December 2002.

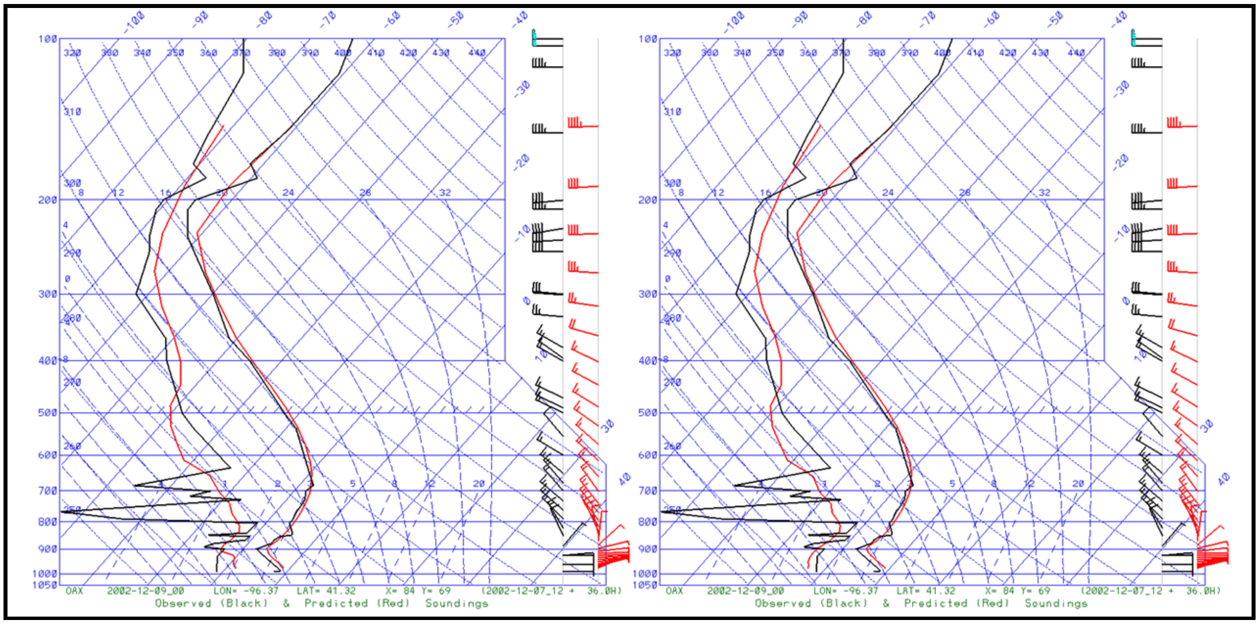

Figure 3-19. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 00Z 9 December 2002.

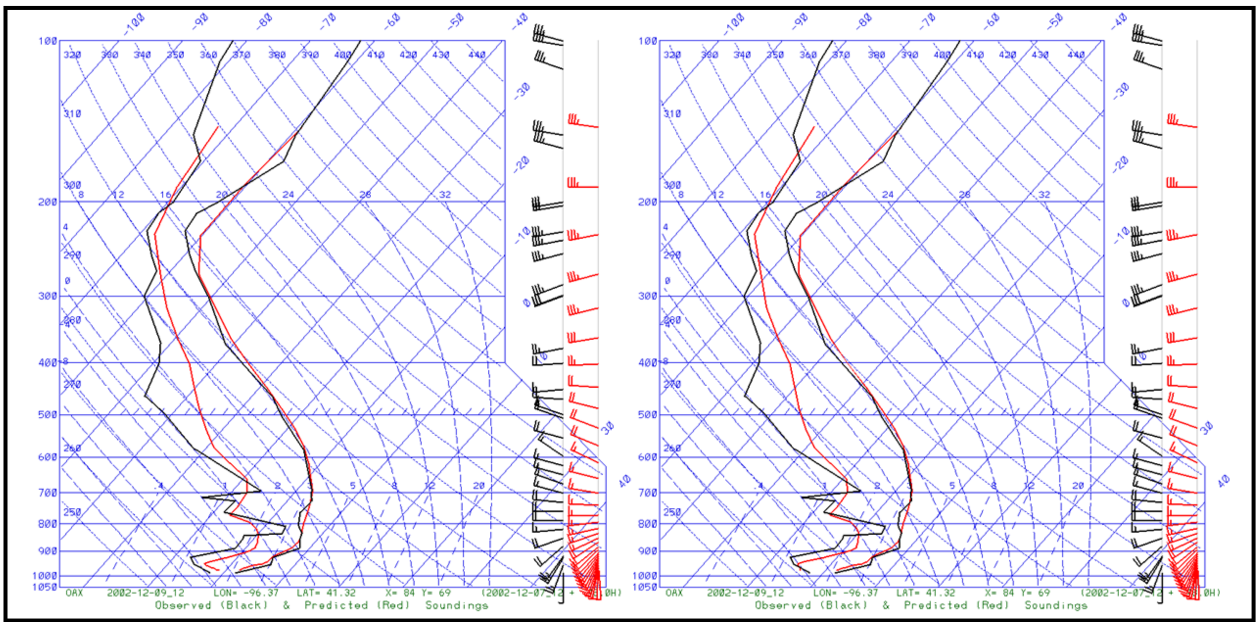

Figure 3-20. Observed versus modeled soundings for v3.6.3 (left) and v3.7.4 (right) at Omaha, NE (KOAX) on 12Z 9 December 2002.

3.3. <u>Precipitation Comparison</u>

The precipitation comparison analysis compared the amount and spatial coverage of modeled precipitation for summer and winter conditions for the two versions of MM5. Like the upper-air comparison, this analysis was a qualitative comparison of the two-dimensional accumulated precipitation field, where the modeled results from both versions were subtracted from the observed precipitation field and also from each other.

Figure 3-21 shows the observed precipitation across the continental U.S. that accumulated from 6 July 2002 through 13 July 2002. This figure shows only precipitation measured over land, thus no assessment of modeled precipitation performance can be made over water. Values of observed precipitation shown over water along coastal areas are an artifact of the objective analysis performed on observed rainfall data, and should be ignored. Figure 3-22 shows the difference between observed and modeled precipitation accumulated across this time period, with observed precipitation acting as the reference. Lastly, Figure 3-23 shows the difference between the modeled precipitation fields output from the two version of MM5. The accumulated precipitation fields for the two adjacent summer blocks show that during summertime conditions both versions of MM5 tended to generally over-predict precipitation, indicated by the negative values in Figure 3-22. During this time period there were two areas of significant precipitation, one in south Florida and the other over Minnesota. There was also a large area over the southeastern U.S. of slight accumulation. Both versions of MM5 over-predicted this area of precipitation along with that over south Florida. The area of high accumulation in Minnesota, however, was under-predicted by both versions of MM5. Results from both versions were generally very similar over land and within one inch of rain accumulated over the summer time period. Differences in rainfall were randomly distributed across the continental U.S., with the exception of the area of rainfall over the Northern Plains where version 3.7.4 under-predicted precipitation relative to version 3.6.3. The lower accumulations of version 3.7.4 occurred over areas where MM5 was over-predicting precipitation relative to observations. This shows the problem of model over-prediction is slightly improved for the newer version of MM5.

During the two adjacent winter blocks a band of moderately accumulated precipitation extended from southeast Texas northeastward to New England, shown in Figure 3-24. A more significant area of precipitation also accumulated over Florida. Figure 3-25 shows both versions of MM5 under-predicted precipitation along the Gulf Coast and across Florida. All other areas of accumulated precipitation were well simulated. Figure 3-26 shows negligible differences in precipitation fields over land modeled by the two versions of MM5. Differences in accumulated precipitation over water were less than one inch.

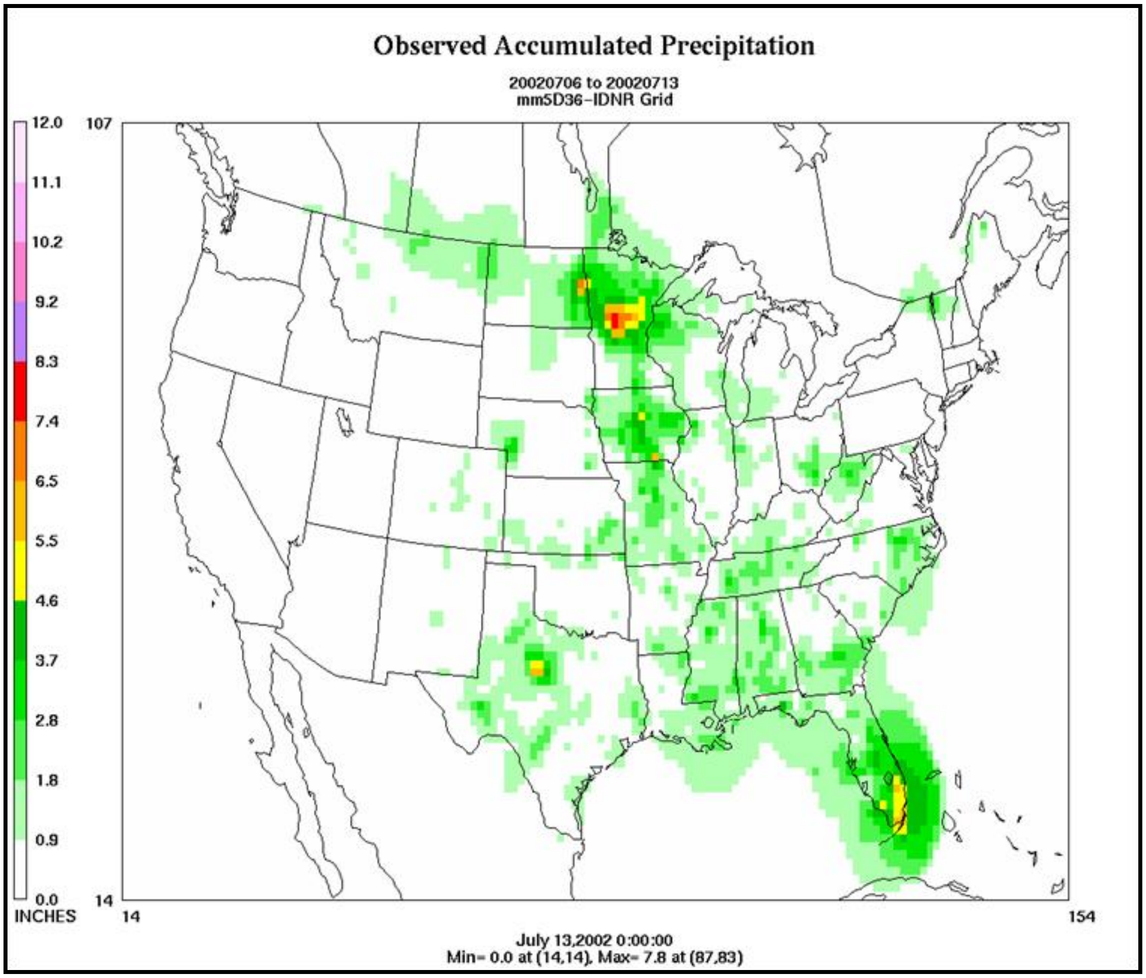

Figure 3-21. Observed precipitation accumulated during the two summer MM5 blocks.

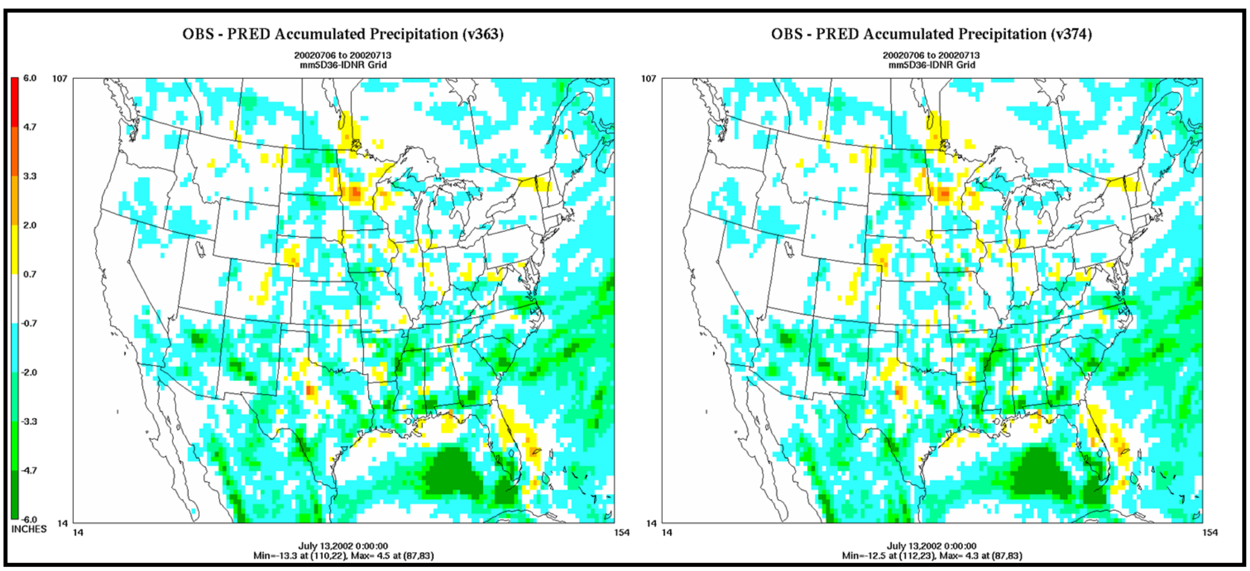

Figure 3-22. Absolute difference between accumulated precipitation observed and modeled by MM5 version 3.6.3 (left) and version 3.7.4 (right) for the two summer MM5 blocks.

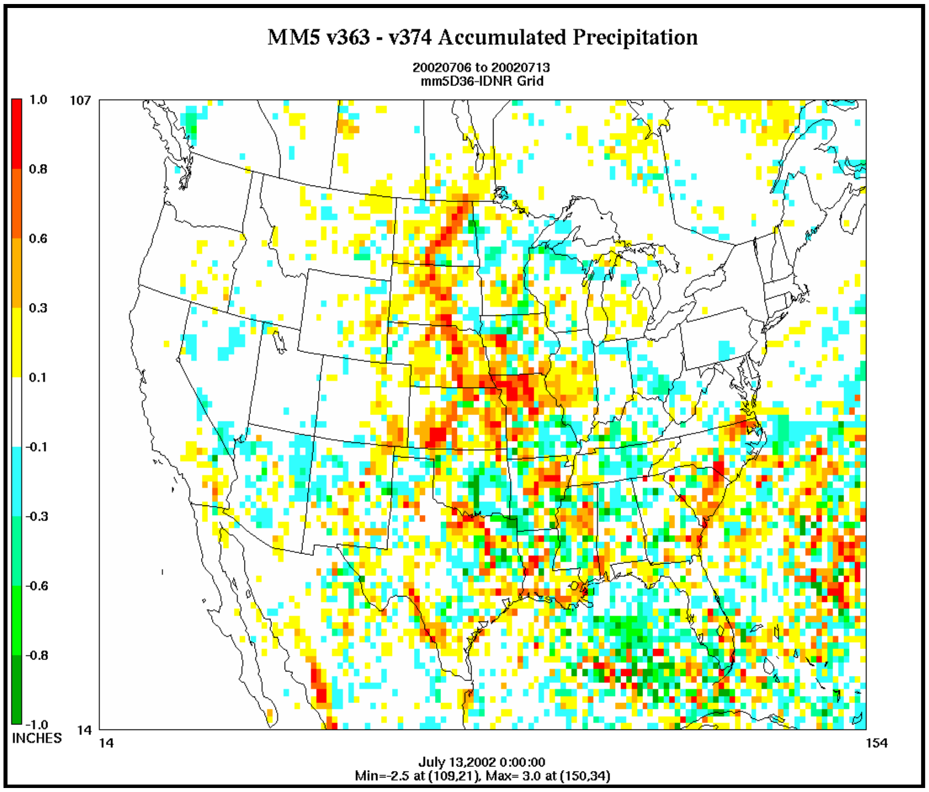

Figure 3-23. Absolute difference between accumulated precipitation modeled by MM5 versions 3.6.3 and 3.7.4 for the two summer MM5 blocks.

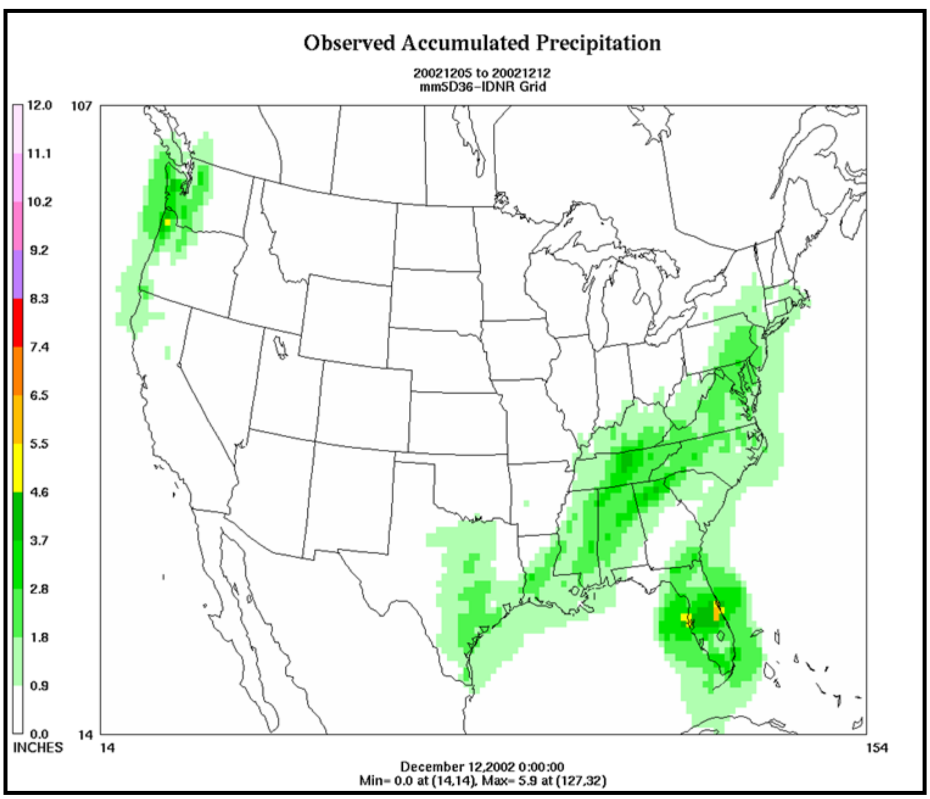

Figure 3-24. Observed precipitation accumulated during the two winter MM5 blocks.

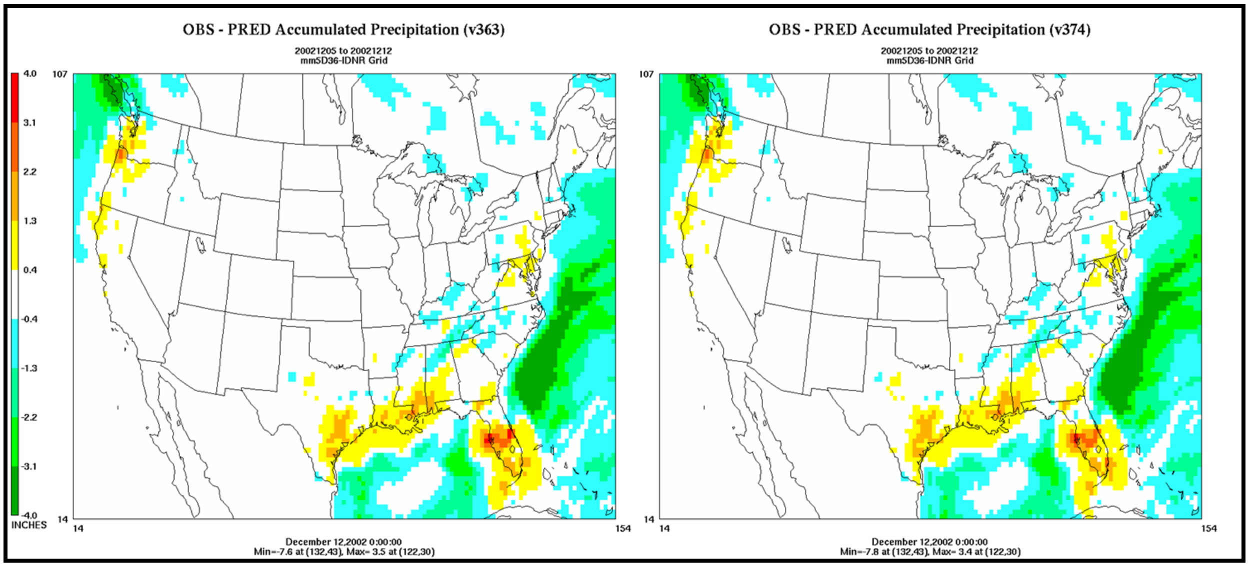

Figure 3-25. Absolute difference between accumulated precipitation observed and modeled by MM5 version 3.6.3 (left) and version 3.7.4 (right) for the two winter MM5 blocks.

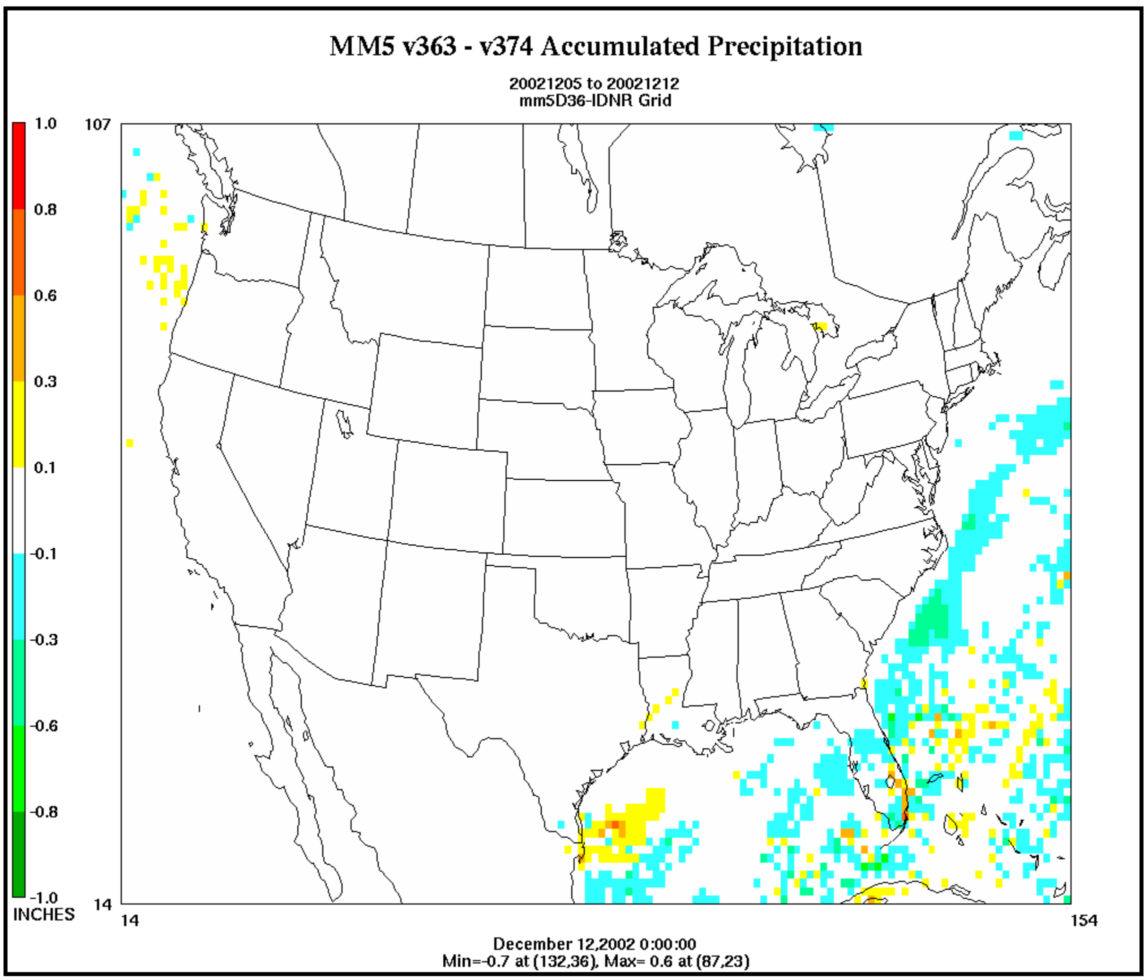

Figure 3-26. Absolute difference between accumulated precipitation modeled by MM5 versions 3.6.3 and 3.7.4 for the two winter MM5 blocks.

4. Conclusions

A new major release of the MM5 modeling system was published since the last annual meteorological simulation was conducted by the Iowa Department of Natural Resources. This release contains various bug fixes and updates to nearly all MM5 processors. An analysis was performed on output from both versions of MM5 to determine the improvement, if any, in model performance. Two time periods were simulated for the year 2002, one to represent summer conditions and the other to represent winter conditions. Two adjacent MM5 5-day blocks from the 2002 annual simulation conducted by IDNR were used for each season. Three analysis methods were employed to characterize the accuracy and similarity in modeled results for both versions of MM5. Error statistics were calculated for surface fields of wind speed and direction, temperature, and relative humidity within two sub-regions of the MM5 domain. Observed versus modeled soundings were generated for the output from both versions, as a qualitative assessment of upper air fields of winds, temperature, and dewpoint. Lastly, observed versus modeled precipitation accumulated across the analysis time periods were generated to qualitatively compare model performance of rainfall.

In general, the error statistics generated by Environ's Metstat program for surface temperature, wind speed and direction, and relative humidity were nearly identical for both the CenrapN and Iowa sub-domains during the summer blocks. The same performance shown by version 3.6.3 was evident in the results of 3.7.4. The one notable difference in the summer was version 3.7.4 generally predicted slightly lower relative humidity. This brought the baseline in bias closer to zero. The error statistics for these surface variables are also nearly identical during the winter analysis period, also. However, during the last half of the winter period when model performance was poor for both versions, version 3.7.4 showed noticeably worse performance in temperature and improved performance in relative humidity, relative to version 3.6.3.

Observed versus modeled soundings were generated at 0Z and 12Z on days during the two analysis periods. The results show the modeled soundings from both versions of MM5 are nearly identical for both day (0Z) and night (12Z) soundings for both seasons. The most noticeable difference between the two versions was in the boundary layer profiles for 0Z soundings during the summer. Results from version 3.7.4 showed a deeper boundary layer and lower dewpoints throughout. This would account for the lower surface relative humidity shown in the surface comparison. However, these differences in PBL heights and dewpoints were not significant.

Lastly, the comparison of precipitation fields shows similarity between both versions' results. Both versions significantly overestimated precipitation during the summer over the southern have of the U.S. but underestimated the magnitude, while overestimating the special extent of a precipitation event centered over Minnesota. However, version 3.7.4 did show some improvement in performance in areas where version 3.6.3 overestimated precipitation. During the winter, a significant precipitation event over Florida was underestimated equally by both versions.

An initial review of model output from both versions of MM5 compiled using PGI versions 5.1, 6.0, and 6.1 revealed that compiler version did not play any role in influencing results, nor did any one compiler produce erroneous or suspicious data. Thus, this analysis was not pursued in more detail.

Overall, the performance of version 3.7.4 was very similar to version 3.6.3. All the strengths and weaknesses in performance exhibited by the older version were also shown in the newer one. Considering the inclusions of bug fixes in the updated model code, in combination with slight improvements in precipitation and PBL depth predictions, it is recommended future simulation utilize the updated version. While this analysis was fairly brief and simplistic, the similarity in performance suggests a more thorough, exhaustive review may not be necessary. Additional simulations of regional emissions and photochemical transport models would be needed to determine the effect any changes in meteorological performance would have on surface pollutant concentrations. However, it is expected these effects are minimal.

5. References

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